§ 23. A Study of a Gas Supply Nozzle for an Energetic Arcjet Plasma Beam

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If the electromagnetic (EM) plasma accelerator works correctly, the system can be quite an intensive heating power source. In particular, the output power density must be as high as ~10^4 times to that of the usual NBI source. This may be easily inferred from the fact that the kinetic energy of the plasma at the initial phase of the pinching devices is extremely high. The big difference arises simply from the fact that the EM force is free from the space charge problem. The efforts for achieving such a high power EM system had started in ~1960. Unfortunately, no successful result has ever reported so far. The key issue for the failures may be ascribed to the plasma source[1, 2]. The source must be the one that yields the plasma of the velocity greater than the thermal's, since the EM force along the flow is shown to decelerate the sub thermal flow. Parker[3] demonstrated that the seemingly paradoxical theorem above actually works; the solar wind is accelerated by the massive gravity of the sun up to quite a high energy. It can be said, therefore, that the paradox is reduced to the fact that the external force modifies the pressure distribution along the flow.

The physics stated above shows the importance of developing the heat engine that boosts up the injected cold gas to the plasma flow of a super thermal velocity. The theoretical considerations of heat engine based on the ideal model[4, 5] suggest the importance of controlling the injection gas velocity into an arcjet system. For such a purpose, use of the Laval nozzle is most convenient. Here, two types of the nozzles shown in Fig.1 were tested; the one of the longer diverging exit channel and the other of much shorter one. For each type, three different throat diameters D_{th} equals to 0.8, 1.0 and 1.2 millimeters, respectively, were tested to confirm which is the most suitable one to extract ~1000 A current equivalent of the hydrogen plasma beam.

In the upstream of the nozzle, the fast acting gas valve, which opens and closes within 300 □s, is mounted for feeding hydrogen gas at the pressure of 300 kPa. The tube connecting the valve and the nozzle can be regarded as a gas reservoir, and the pressure inside is monitored by a piezo type probe. In the downstream of the nozzle, the arcjet and the EM accelerator of the Faraday type are mounted. For studying how the gas fills up the system, the dynamic pressure was measured on the end plane of the EM accelerator by scanning across the aperture. It was found that for D_{th}=1.0 and 1.2 cases thin and intensive gas beam is observed. Other eminent features noticed in the experiment may be in the fact that gas injection rate sharply decreases for D_{th}=0.8 mm nozzle. This suggests that the boundary layer of the thickness ~0.4 mm develops across the throat.

References:

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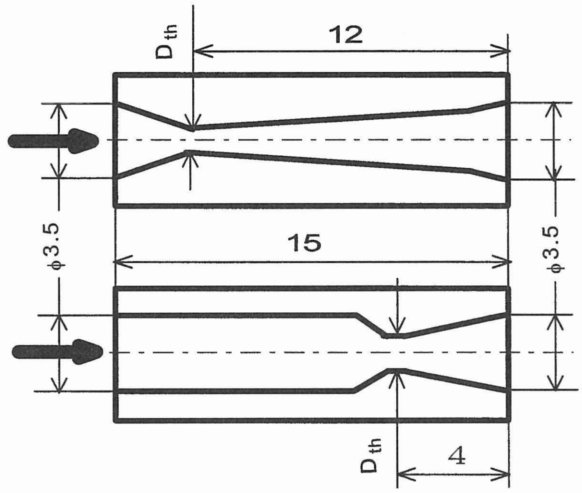

Fig.1: Two types of the gas feed nozzle are studied. The upper one has longer gas expansion of 12 mm, while the lower of 4 mm. For both type, three different throat diameters D_{th} of 0.8, 1.0 and 1.2 mm are tested.

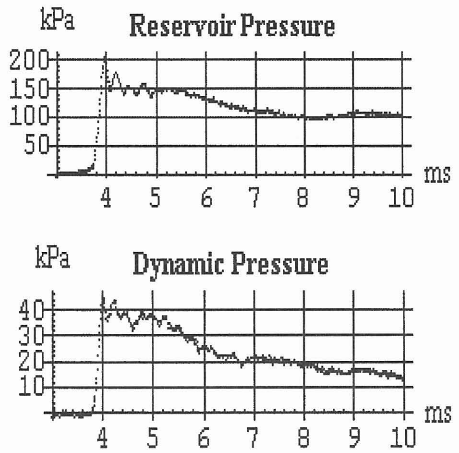

Fig 2: Typical pressure response of the reservoir and the sharp dynamic pressure on the downstream end of the Faraday accelerator. The lower signal appears only for the long expansion nozzle of the throat 1.0 and 1.2 millimeter diameter case.